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The main objective of this project was to characterize the linear and non-linear infrared optical properties of technically important semiconductors in varied sample geometries, such as bulk, near a surface and in a film geometry. Suface polaritons and guided-wave polaritions in GaP and GaSe were studied by Raman scattering spectroscopy. Resonance Raman effects were investigated at the indirect gap of Ga P. The structure of amorphous Se-Ge glass was determined by Raman scattering. A double grating spectrometer and a Fabry-Perot interferometer were interfaced to an LSI-11 minicomputer using a CAMAC system.

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FINAL SCIENTIFIC REPORT

Grant No. AFOSR-77-3222

Light Scattering Studies of Far Infrared Dielectric Properties of Semiconductors

Period Covered: January 1 , 1977 - December 31,1981

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This report covers the period between January 1, 1977 and December 31, 1981. The original grant period which was to end on September 30, 1981 was extended at no cost to December 31, 1981.

I. Research Objectives

The main objective of this project is to characterize the infrared properties of technically important semiconductors in varied sample geometries, such as bulk, near a surface and in a film form. The ifnrared properties of semiconductors are determined by the behavior of elementary excitations in the sample having the quantized energies in the far infrared range. The above objective is accomplished by determining the energies, life-times and the interaction strengths with the electromagnetic radiation of phonons, polaritons and plasmons by means of light scattering spectroscopy.

II. Significant Accomplishments

Surface polaritons and guided-wave polaritons were studied in thin slabs of GaP by means of Raman scattering spectroscopy. The diserpsion, linewidths and Raman scattering selection rules were determined. The effect of surface roughness on surface polaritons was also determined for GaP samples with varied surface roughness. The results generally agreed with the existing theory. However, the Raman intensities of surface polaritons in a roughened surface were found to be anomalously high. This effect was later explained by French theorists (Neviere and Reinisch) as due to the enhanced electric field strength of the incident laser field near a rough surface.

A theory of surface polaritons (plasmons) in doped

semiconductors with an electrical current inside was developed. This theory predicted the existence of certain instabilities.

A resonance Raman effect was observed at the indirect gap of GaP, and a detailed excitation profile that shows different phonon assisted transitions was obtained for the first time. Another resonance Raman measurement was carried out in a magnetic semiconductor, cadmium-chromium-sulfide.

The structure of amorphous Se-Ge glass was studied by Raman scattering. It was found that for Ge-content of less than 50 percent the bonding structure is based on 4-2 coordination while the coordination changes to 3-3 for a higher Ge-content.

A complete study of surface polaritons including guided-wave polaritons was carried out on GaSe thin films. The results allowed precise determination of the dielectric functions of GaSe in the far infrared.

A double grating spectrometer and a Fabry-Perot interferometer were interfaced to an LSI-11 minicomputer using a CAMAC system. The Fabry-Perot interferometer is stabilized by software control for continuous use without manual adjustment.

III. Publications

1. Selection Rules in Raman Scattering from Surface Polaritons, J. B. Valdez and S. Ushioda, Phys. Rev. Letters 38, 1098 (1977).
2. Raman Scattering Selection Rules for Surface Polaritons, J. B. Valdez and S. Ushioda, Proc. of Int. Conf. on Lattice Dynamics (Paris, 1977), ed. by M. Balkanski, p. 318.
3. Instability and Stability of Surface Modes in Phonon-Plasmon System in a Semiconductor, T. Tajima and S. Ushioda, APS Bull. 22, 179 (1977).
4. Raman Scattering Selection Rules for Surface Polaritons, J. B. Valdez and S. Ushioda, APS Bull. 22, 178 (1977).
5. Surface polaritons in LO phonon-plasmon coupled systems in semiconductors, T. Tajima and S. Ushioda, Phys. Rev. B18, 1892 (1978).
6. Light scattering spectra of guided wave polaritons in thin crystals--Experiment, J. B. Valdez, G. Mattei and S. Ushioda, Solid State Comm. 27, 1089 (1978).
7. Light scattering studies of surface polaritons in thin semiconductor slabs--Effects of surface roughness, S. Ushioda, A. Aziza, J. B. Valdez and G. Matteri, Proc. of Int. Conf. on the Physics of Semiconductors, (Inst. of Physics, Bristol & London, 1979) p. 207.
8. Effects of surface roughness on surface polaritons, S. Ushioda, A. Aziza, J. B. Valdez and G. Mattei, Phys. Rev. B19, 4012 (1979).
9. Observation of guided-wave polaritons in thin crystals, J. B.

Valdez, G. Mattei and S. Ushioda, Bull. of APS, 23, 278 (1978).

10. Spectroscopic Studies of the Structure of Amorphous Se-Ge, H. Kawamura, M. Matsumura and S. Ushioda, J. Non-Cryst. Solids 35-36, 1215 (1980).
11. Resonance Raman Scattering in $CdCr_2S_4$: Magnetic Circular Polarization Properties, N. Koshizuka, S. Ushioda and T. Tsushima, Phys. Rev. B21 1316 (1980).
12. Light Scattering Spectroscopy of Surface Electromagnetic Waves, S. Ushioda, Progress in Optics, Vol. 19, ed. by E. Wolf, (North-Holland, Amsterdam, 1980), p. 139.
13. Raman Scattering by Surface Polaritons, S. Ushioda and R. Loudon, Surface Polaritons, ed. by D. L. Mills and V. M. Agranovich, (North-Holland, Amsterdam, 19xx) in press.
14. Resonance Raman Scattering at the Indirect Gap of Gallium Phosphide, M. Udagawa, S. Ushioda, D. E. Forsyth and J. B. Valdez, Proc. of Int. Conf. on the Physics of Semiconductors-Kyoto, J. Phys. Soc. Japan 49, 555 (1980) Suppl.
15. Surface Electromagnetic Waves (SEW) in the Far Infrared, SPIE Proceedings, Vol. 239, 116 (1980).
16. Guided Wave Polaritons in GaSe Films, Y. Sasaki and S. Ushioda, APS Bulletin 27, 164 (1982).

IV. Papers in Preparation

1. Guided-wave Polaritons in Thin Films of the Layered Compound GaSe, Y. Sasaki and S. Ushioda.
2. Theory of Resonance Raman Scattering at the Indirect Gap of GaP, S. Ushioda.

V. Personnel

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M. Udagawa (Post-doctoral)

Y. Sasaki (Post-doctoral)

W. Sasaki (Visitor from Japan)

Graduate Students: J. B. Valdez

I. S. O. Muokebe

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D. E. Forsyth

VI. Degrees Granted: I. S. O. Muokebe, Ph.D. (1977).

Dissertation title: Raman Spectra of Silicon Nitride and Doped GaAs.

J. B. Valdez, Ph.D. (1978)

Dissertation title: Surface Polaritons and Resonance Raman Scattering in GaP.

VII. Coupling

Collaboration arrangements wre made with

1) Derek Cheung, Rockwell International Science Center

2) F. H. Pollak, Brooklyn College

3) P. W. Kruse and M. A. Kahn

Honeywell Corporate Materials Sciences Center

to work on (HgCd)Te. Samples of silicon nitride were provided by AFML - Dayton, Ohio.

VII. Patents: None